DESCRIPTIVE REPORT PR53-1

Contract NOnr-08602

BATHYTHERMOGRAPH DATA ANALYZER

By

8100 Monticello Avenue
SKOKIE, ILLINOIS

A DIVISION OF COOK ELECTRIC COMPANY

Descriptive Report PR 53-1

BATHYTHERMOGRAPH DATA ANALYZER

Contract NOnr - 08602

Project No. P-417

In Reply Please
Refer to P-417

TELEPHONE KEYSTONE 9-2060

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8100 MONTICELLO AVENUE SKOKIE, ILLINOIS

5 June 1954

Department of the Navy
Office of Naval Research
Undersea Warfare Branch (Code 466)
Washington 25, D. C.

Attention: Lt. James E. Lesch

Subject: Descriptive Report PR 53-1
BATHYTHERMOGRAPH DATA ANALYZER
Contract NOnr-08602

Gentlemen:

We are enclosing a descriptive report on the Bathythermograph Data Processing Equipment developed by Cook Research Laboratories under the subject contract. This report shows how the equipment operates, describes major components, explains the operations it is designed to accomplish, and gives a detailed description of a typical operation (averaging).

It is believed that this report will facilitate a wider understanding of the objectives and accomplishments of this program.

Very truly yours,

COOK ELECTRIC COMPANY

R. C. Edwards

R. C. Edwards, Business Manager
Cook Research Laboratories Division

RVC:emh

DESCRIPTIVE REPORT PR 53-1

TITLE: BATHYTHERMOGRAPH DATA ANALYZER

CONTRACTOR: COOK ELECTRIC COMPANY
Cook Research Laboratories Division

CLIENT: Department of the Navy
Office of Naval Research

DATE: 3 June 1954

CONTRACT NO. Contract No. NOnr-08602

This report was prepared by the Engineers of the Cook Research Laboratories and compiled by Leo G. Killian, Executive Engineer under the direction of J. Robert Downing, Ph. D., Director.

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SECTION I

INTRODUCTION

The Cook Research Laboratories Bathythermograph Data Analyzer was built for the Office of Naval Research under Contract NOnr 08602. Its primary function is the semi-automatic statistical analysis of Bathythermograph slide records of water temperature versus pressure-depth; however, with suitable input equipment it could be used for the analysis of any large-scale collection of data.

The Data Analyzer (shown in Fig. 1) occupies an area approximately 20 ft by 10 ft in a room set aside for it. Auxiliary equipment housed with it include a viewer for close examination of the film records and an IBM card punch for preparing the auxiliary data cards.

This report is limited to a brief general description of the data analyzer and its functioning. The reader who is interested in a more detailed account is referred to Final Progress Report FPR 35-1 of these laboratories.

SECTION II

FILM RECORD

The record produced from the B. T. slides by the Data Analyzer and used by it in all further operations consists of a pattern of black lines and areas photographed on 70 millimeter microfilm. A typical frame of the record is shown in Fig. 2. Item 1 in this figure is the image of the Auxiliary Data Card, an IBM card photographed one-eighth actual size. Holes are punched in the card to identify the B. T. data: B. T. number, cruise number, drop number, date, time latitude, longitude, weather conditions, cloud cover, and other pertinent information.

Item 2 is the Frame Reference Line which serves as a registration mark in the use of the film.

Item 3 is the row of P-Lines. Each of these lines represents an increase of one foot of pressure-depth. Thus the first line represents one foot, the second line two feet, and so on. This scale normally extends to the depth to which the B. T. was dropped, with 450 ft as a maximum. However the scale can be any desired length to fit specific data.

An extension of one of the P-Lines across the film will cross a number of T-Lines (Item 4). The number of T-Lines crossed indicates the value of the temperature at the pressure-depth corresponding to the P-Line under consideration. (The whole record is, in effect, an ordinary graph of pressure-depth vs. temperature with a calibration grid superimposed on it to make it digital in nature.) The primary scale used has 599 T-Lines, covering the range of 30.0°F to 89.9°F in 0.1°F increments. Thus zero T-Lines represent 30.0°F, one line represents 30.1°F, seventeen lines represent 31.7°F, 598 lines represent 89.8°F. Other scale factors may be used for other purposes, as desired. Another grid in use has 198 lines, 99 positive and 99 negative, with zero at the center. It is used to represent values from positive 9.9°F to negative 9.9°F in 0.1°F increments. Alternatively, it can be used to represent a 9.9° range above and below any selected center value, or other scale factors may be used. A typical frame of record using this grid is shown in Fig. 3.

An additional indication of whether a T-Value is positive or negative is given by the T-Polarity indication (Item 5). This region of the film is transparent when the T-Value directly above it is positive, black if the T-Value is negative. This may be observed in Fig. 3, which has both values.

Item 6 is the Auxiliary Data Card for the next frame of data; Item 7 is the end of the preceding frame. Each record occupies approximately two inches along the length of the film. A 100 ft roll of film will hold 600 records.

The form used for the records ("Unitary Digital") permits automatic playback of the film by using phototubes to count the P-Lines and T-Lines with the precision inherent in digital systems. It also permits the observation, analysis, and comparison of the records by eye (with or without a projector) since it preserves the basic nature of the data in graph form. Even in this use, however, values are read from the film digitally, thus with high accuracy. The record may even be scanned with simple analog-type devices if desired. Thus it is a truly universal record form.

SECTION III

MAJOR EQUIPMENT COMPONENTS

A. Slide Scanner

The Bathythermograph Slide Scanner (Fig. 4) is the unit in which the data from the B. T. slides are converted into series of electrical pulses which actuate the recording equipment. To begin recording, the operator inserts a B. T. slide into the slide holder. An enlarged image of the slide is automatically projected onto a table. (See Fig. 5). This table is free to swing about a pivot, but is held rigidly at a fixed distance from the pivot. The operator swings the table around the pivot until a small hole in the table comes under the projected image of the trace of the B. T. slide. Light from the trace passing through the hole strikes a phototube operating circuitry which causes the projected trace to move toward the operator. The operator then moves the table from side to side in such a way as to keep the hole always under the moving trace until the end of trace is reached. If the hole is allowed to leave the trace, the phototube circuit is automatically de-energized, stopping the trace movement until the hole is moved back into position. (In case of a bad trace this feature may be overridden by a hand switch.)

As the trace moves forward a circuit generates a series of pulses, one pulse for each increment of trace advance equal to a foot of pressure-depth. These pulses occur at a rate of about 10 per second; it takes about 45 seconds to scan a 450 ft slide. Immediately following each of these pressure pulses, a burst of pulses is generated in a second circuit. The number of pulses in this burst varies with the position of the table, being zero if the table is all the way to the right and 599 if it is all the way to the left. Since the hole must be kept under the trace in order for the trace to move and cause pressure pulses to be generated, the burst of pulses (temperature pulses) will vary in number with the temperature traced on the slide. The zero to 599 pulse range of the table corresponds to a temperature range of 30.0°F to 89.9°F in 0.1°F steps.

Calibration adjustments are provided on the Slide Scanner for the major B. T. variations. With the B. T. calibration grid in the slide holder, adjustments are made to compensate for the radius of the constant pressure lines, the length of the temperature scale, the length of the pressure scale, and the pressure sensitivity of the temperature scale. Once these adjustments have been made, the calibration is satisfactory for any slide from the B. T. for which the calibration was made, without further calibration.

A chart of the scanning errors in the Slide Scanner when scanning a typical B. T. calibration grid is shown in Fig. 6. It can be seen that the

errors on the pressure scale do not exceed one ft and over most of the image do not exceed one-half ft (these figures should be doubled for a 450 ft B. T.), while the temperature scale errors do not exceed two-tenths of a degree, and over most of the grid do not exceed one-tenth degree. These errors will of course, depend on the linearity of the pressure and temperature scales of the individual B. T. calibration grid.

An operator with a few hours experience can record B. T. slides at a rate of about 30 per hour. Calibration adjustments for a grid take only a few minutes and need only be made when the operator starts a batch of slides from a new B. T.

B. The Recorder

The Recorder (Fig. 7, 8, 9) is the unit in which the film record is made. The Auxiliary Data Card and Frame Reference Line are photographed at the beginning of a frame of recording by the flashing of a lamp (Item 1 in Fig. 10). Each P-Line with its corresponding row of T-Lines is photographed individually by a very short flash of another lamp (Item 2). This lamp when it flashes, illuminates a portion of the "Tabular Screen" (Item 3), a rotating glass disc bearing a pattern of lines (shown in detail in Fig. 11) and projects an image of it onto the aperture plate (Item 4). This plate has a very narrow slit across it which allows a narrow portion (about three-thousandths of an in. wide) of the screen to be photographed onto the film. The position of the rotating disc at the time of the flash is determined by a phototube (Item 5) which counts the short lines around the edge of the disc. The lamp is flashed automatically when the phototube has counted enough of these lines to bring the correct portion of the screen over the slit to record the desired number of T-Lines. The film then advances three-thousandths of an in., and the next P-Line and corresponding T-Value are recorded.

The tabular screen for recording values from +99 to -99 T-Lines is shown in detail in Fig. 12.

C. The Playback Scanner

The Playback Scanner (Fig. 13) is the unit which recovers the information from the recorded film in all the statistical operations subsequent to recording of the slides. The film (Item 1, Fig. 14) slides across an aperture plate (Item 2) and is illuminated by a lamp (Item 3). As the frame reference line on the film (Item 4) crosses the frame reference slit on the aperture (Item 5) a pulse is produced in a phototube (Item 6) which is used as a registration indication and to count the number of frames scanned. Simultaneously the Auxiliary Data Card (Item 7) will be over the opening in the aperture (Item 8) so its image will be projected through the opening, reflected by the mirror (Item 9), focused by the lens (Item 10) and projected (enlarged to the full size of the original IBM card) onto the Auxiliary

Data Selection Card, an IBM card in a holder (Item 11). This selection card has punched in it a pattern of holes representing the auxiliary information which it is desired to use as a basis for selection of the frames to be analyzed. This auxiliary information may be any item of data normally punched into the Auxiliary Data Card. Thus, it is possible to select on the basis of a particular date or range of dates, a given latitude or range of latitudes, a given set of weather conditions, or any item or combination of items of the auxiliary data. If the frame of film passing the aperture has information punched into its Auxiliary Data Card which fits the selection data a pulse will be produced by the phototube (Item 12) which will cause the data on the frame to be scanned; if not the frame will be rejected.

Light variations caused by the P-Lines and T-Polarity region of the film (Item 13) passing over a slit in the aperture (Item 14) fall on two phototubes (Items 15 and 16). One phototube produces one pulse as each P-Line crosses it; the other produces an indication of the polarity (positive or negative) of the T-Value corresponding to each P-Line. At the same time that each P-Line is producing its pulse from the phototube, the corresponding T-Lines are being projected through the same slit and focused by a lens (Item 17) onto the surface of a glass scanning disc (Item 18). This disc is opaque except for eight curved transparent slits and is rotating at high speed. Thus the slits scan the image of the T-Lines which appears on its surface, producing a series of light pulses on the phototube behind the disc (Item 19). The number of these pulses in one scan is equal to the number of T-Lines recorded on the film at that point. The second slit and phototubes (Items 20, 21, 22, and 23) simultaneously scan a second P-Line separated from the first by five, ten, or twenty-five P-Lines (depending on the aperture in use) and the T-Polarity and P-Line indications which go with it. The use of two slits simplifies the taking of differentials.

SECTION IV

ELECTRONICS UNIT CHASSIS - THE BUILDING BLOCKS

The pulse handling and computing functions of the Data Analyzer are performed in the electronics racks (Fig. 15). These hold the unit chassis which contain the electronic circuitry required to perform the various operations. In use, the unit chassis are interconnected by a system of short coaxial cables to form the desired combination of circuits. This makes a very flexible arrangement in which it is possible to make changes and modifications to existing setups and to experiment with new setups of widely differing types with a minimum investment of time and no new equipment construction. Figure 16 shows the back of the electronics racks with the unit chassis connected for use. Figures 17 and 18 show some of the unit chassis.

A few of the unit chassis are of special types, each designed to fill some special need; however most of them are of a few types, each type designed to perform one of the principal pulse handling functions. Almost any pulse handling function can be performed by the proper combination of enough of these standard units. A brief functional description of some of these units follows.

A. Gate

The gate is an electronic switch. It is turned on by a pulse on the "On" terminal and off by a pulse on the "Off" terminal. So long as the gate is in the On condition pulses on the "Input" terminal will be passed through to the "Output" terminal; if it is in the Off condition they will not pass through. Fifteen gate chassis are included in the present equipment.

B. Counters

Two types of counter chassis are in use. The low-speed counter counts up to 40,000 pulses per second; the high-speed counter up to 1,000,000 per second. Both types consist of three decades which count up to 999 then repeat. They can, however, be cascaded to make any desired counting capacity. Both types can be instantly reset to zero electrically by pulses. The number to which the counter has counted is at all times displayed on illuminated scales on the front of the counter. The analyzer presently contains 6 high-speed counters and 5 low-speed counters.

C. Preset Counter

This unit is a three digit indicating counter which will count up to 100,000 counts per second. It can be preset by switches to any number from 1 to 999 so that it will produce an output pulse when its count reaches the preset number. It can also be reset to zero by a pulse on the "Reset" terminal. Only one preset counter chassis is presently in use, however, one preset decade chassis is also available. This differs from the preset counter in that it is only a single decade counter which counts only to nine. It can be preset to any number from one to nine.

D. Pulse Generators

Two types of pulse generators are in use. The low-frequency pulse generator can be used self-triggered at selected rates from 1 pulse per second to 40,000 pulses per second and externally triggered at any rate up to 40,000 per second. The high frequency oscillator is free-running over the

range of 1,500 to 1,000,000 pulses per second. At the present time, three low-frequency pulse generators and one high-frequency oscillator are available.

E. Delay Generators

Two types of pulse delay chassis are in use. The delay line chassis will delay a pulse up to one microsecond in one-tenth microsecond steps; the delay multivibrator chassis has a delay continuously variable from five microseconds to one-half second. Two delay line chassis and three delay multivibrator chassis are presently in use.

SECTION V

OPERATIONS

The standardized unit chassis can be interconnected in an almost limitless number of combinations to perform almost any imaginable statistical operation on the data which has been recorded on the film. Some of the operations which have been used or will be used soon are described below. Many variations of each operation are possible.

A. Original Recording

Film records of B. T. slides are normally made using a P-Scale of one line per ft and a T-Scale of 600 lines, covering the range of 30.0°F to 89.9°F in 0.1°F increments. However, other scales may be used if desired. For example, two P-Lines per foot is used with slides from 225 ft B. T.'s for greater resolution. For special purposes input devices can be built to read any sort of data into the recorder where it can be recorded with the 599 line screen, the 198 line screen, or with a screen specially drawn to have the desired scale.

B. Reproducing

Extra copies of the film record may be produced by reading the original film in the playback scanner and feeding the data thus obtained into the recorder. Either the original Auxiliary Data Cards, new Auxiliary Data Cards, or a Master Auxiliary Data Card may be recorded on the new film. Scales may be shifted or calibrations introduced if desired.

C. Tabulating

By inserting an Auxiliary Data Selection Card punched with the desired information into the playback scanner and running a roll of film records through, it is possible to count the number of slides on the roll which match the values or ranges of values of auxiliary data punched onto the card. If

desired, the slide numbers may also be noted. The output of the analyzer in this case will be numbers indicated on the illuminated dials of the counter chassis.

D. Average Temperature

A roll of slide film may be run through the playback scanner, frames selected on the basis of auxiliary data by a selection card, and the value of T at any preset value of P on each selected frame read from a counter. Alternatively, the summation of these T-Values may be read at the end of the roll and divided by the number of selected frames (displayed on another counter) to obtain the average temperature at the preset pressure for all the selected frames. Variations of this operation include averaging at several P-Values in one run and determining the average temperature over a given range of pressure for each selected frame.

E. Average Pressure

In this operation frames are selected on the basis of auxiliary data, selected frames are scanned, and the P-Value for which a preselected T-Value first occurs on each frame is indicated on the counters. Variations include summation of the selected P-Values for averaging, summation of the T-Values occurring after the desired T-Value, summation of the T-Values occurring before the desired value, or other combination which may be desired.

F. Maximum or Minimum Temperature

The film may be run through the playback scanner, frames selected by the selection card, and the maximum (or minimum) temperature value of each selected frame indicated on the counters along with the pressure value for which it occurs. Possible variations include summation of these T- and P-Values for averaging.

G. Differentiation

Differentiation of the film records (selected by the auxiliary data) is accomplished by taking the difference between the temperature value associated with each pressure value and the T-Value associated with the P-Value which is 25 P-Lines farther along the record. This gives a differential base which with normal scale factors is 25 ft. The output data from this operation is a new film containing curves which are the derivatives of the curves on the original records. This film is recorded with the 198 line screen giving a range of +9.9°F to -9.9°F in 0.1°F steps. Variations of this operation include use of a differentiation base of five or ten P-Lines.

H. Integration

Integration is performed as a summation. As selected frames are scanned, the T-Values are summed, divided by a constant, and recorded on a new film. Thus the new output film contains curves which are the integrals of the original curves, that is, the value of T recorded for each value of P is equal to the sum of the T values for all previous P values on that frame divided by a constant. Variations of this operation include the use of either the +599 line screen or the +99 to -99 line screen, the use of either film or counter output, and the integration of either whole frames or selected portions of frames.

The solution of an actual problem with the Data Analyzer may involve the use of several of the above operations performed successively or simultaneously. Other operations may be planned to fit special needs.

SECTION VI

A TYPICAL OPERATION - AVERAGING

To show the manner in which the unit chassis are interconnected to perform an operation, a description will be given of a simplified small-scale operation. We will assume we have a roll of film records of B. T. slides and wish to determine the average temperature at a depth of 10 ft for all slides which were made between 5 and 6 A. M. We will further assume that the first slide on the roll was not taken between 5 and 6 A. M., that the second was, and that the temperature at 10 ft of depth on the second slide was 56.3°F, recorded as 263 T-Lines.

The unit chassis are interconnected as shown on the block diagram of Fig. 19, the two gates set to the "Off" condition, the four counters reset to zero, the preset counter switches set to 10 (the desired depth in ft), an Auxiliary Data Selection Card punched to select the 5 to 6 A. M. interval inserted into the card holder, and the film drive started. At point 1 on the timing diagram (Fig. 19) the Auxiliary Data Card associated with the first frame of film is crossing the aperture. However, since the first slide was not taken between 5 and 6 A. M., no pulse is produced on the Match line from the Playback Scanner. At point 2 the first P-Pulse appears on the P-Line followed immediately by the first group of T-Pulses on the T-Line. Since Gate 1 and Gate 2 are both in the "Off" condition neither the P-Pulse nor the T- Pulses can penetrate farther into the circuitry than the gate inputs. At point 3 the second P-Pulse and second group of T-Pulses appear to be followed by more until the end of the frame is reached at point 4. At this point no

change has taken place in the settings of any of the gates or counters.

At point 5 the Auxiliary Data Card of the second frame crosses the aperture and, since this slide was taken between 5 and 6 A. M., a pulse is produced on the Match line from the Playback Scanner. This pulse turns gate 1 "On" and makes the count on low-speed counter 1 change from zero to one. At point 6 the first P-Pulse of this frame appears on the P-Line from the Playback Scanner and is applied to the input of gate 1. Since the gate is now "On" the pulse passes through to the preset counter, causing its indication to change from zero to one. Immediately after this, the first group of T-Pulses appear on the T-Line from the Playback Scanner, but, since gate 2 is still closed, they have no effect on the operation. At point 7 the second P-Pulse appears, passes through gate 1 and is counted by the preset counter. This sequence of events continues until point 8 when the tenth P-Pulse is counted by the preset counter. Since this unit was preset to ten, the tenth input pulse causes it to produce an output pulse. This output pulse turns gate 1 "Off", resets the preset counter to zero, and turns gate 2 "On". Now when the burst of T-Pulses corresponding to the tenth P-Pulse appear at the input of gate 2 they pass through into the high-speed counter. Since the temperature on the film at this point was assumed to be 56. 3°F there will be 263 pulses in this burst and the counter will now indicate 263 at point 10. The next P-Pulse at point 11 can not pass through gate 1 which is now "Off", but will turn gate 2 "Off" so no more T-Pulses can pass through it. From point 12 on, until the end of the frame (point 13), the P-Pulses and T-Pulses can not change the state of the gates or counters.

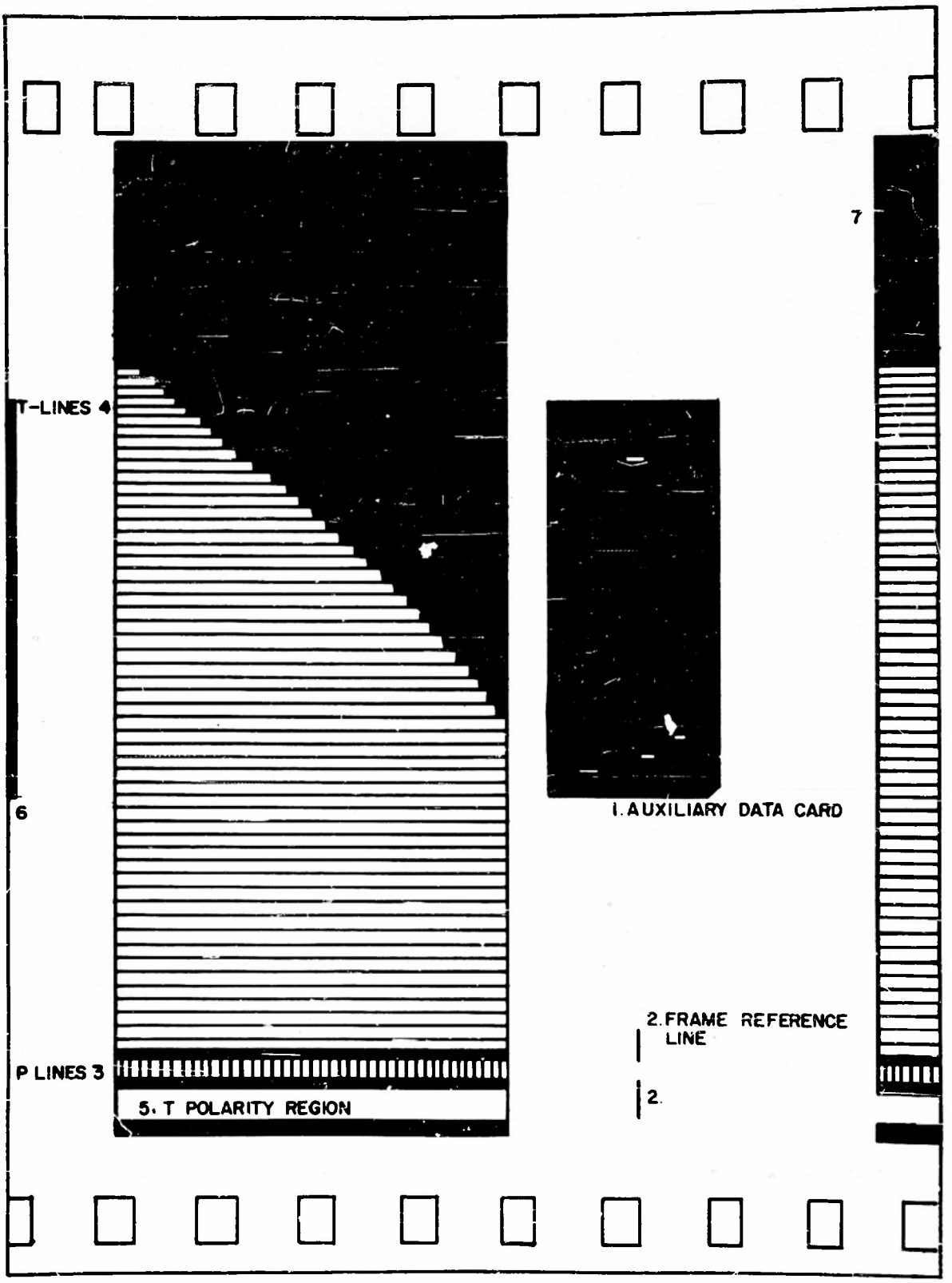
This sequence of operations continues until the end of the roll of film with the count of low-speed counter 1 being increased by one each time a slide which was taken between 5 and 6 A. M. is reached and the count of the high-speed counter increasing by the number of T-Lines corresponding to the tenth P-Line on each such selected frame. Low-speed counter 2 is used to extend the range of the high-speed counter to six digits. When the end of the roll of film is reached, it is only necessary to divide the indication of the combination of the high-speed counter and low-speed counter 2 by the indication of low-speed counter 1 to get the average T-Value at the 10 ft depth of the 5 to 6 A. M. slides. This figure corresponds to the temperature in tenths of a degree fahrenheit above 30 degrees.

The operation described in this example is very simple and straightforward. Most of the operations use many more unit chassis, however, the basic principles of operation are similar.

8013A (R02594)

Fig. 1 - Bathermograph Data Analyzer

SK-6828



599 LINE FILM RECORD (SIMPLIFIED)

FIG 2

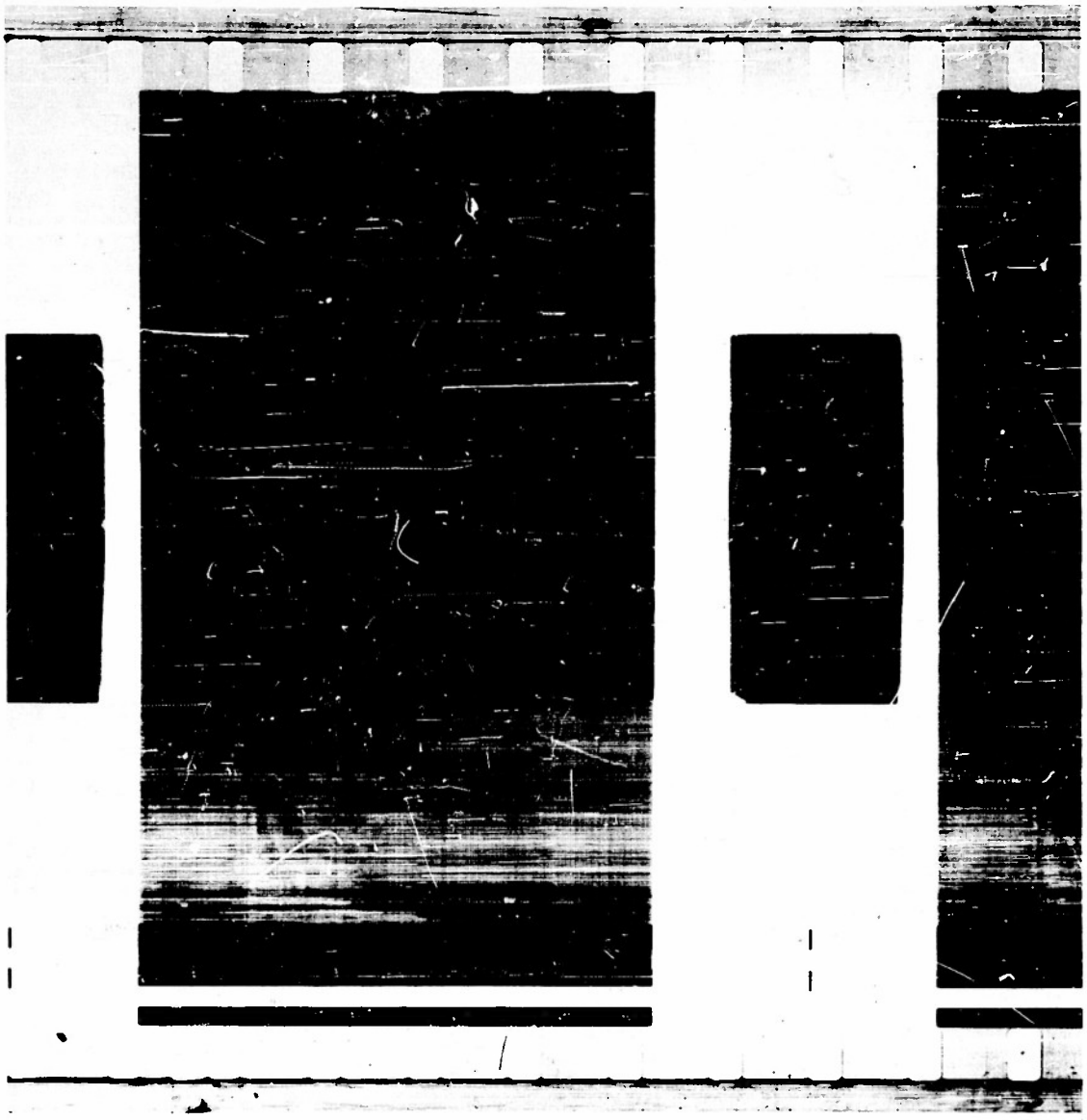


Fig. 2a - Photograph of 599 Line Film Record

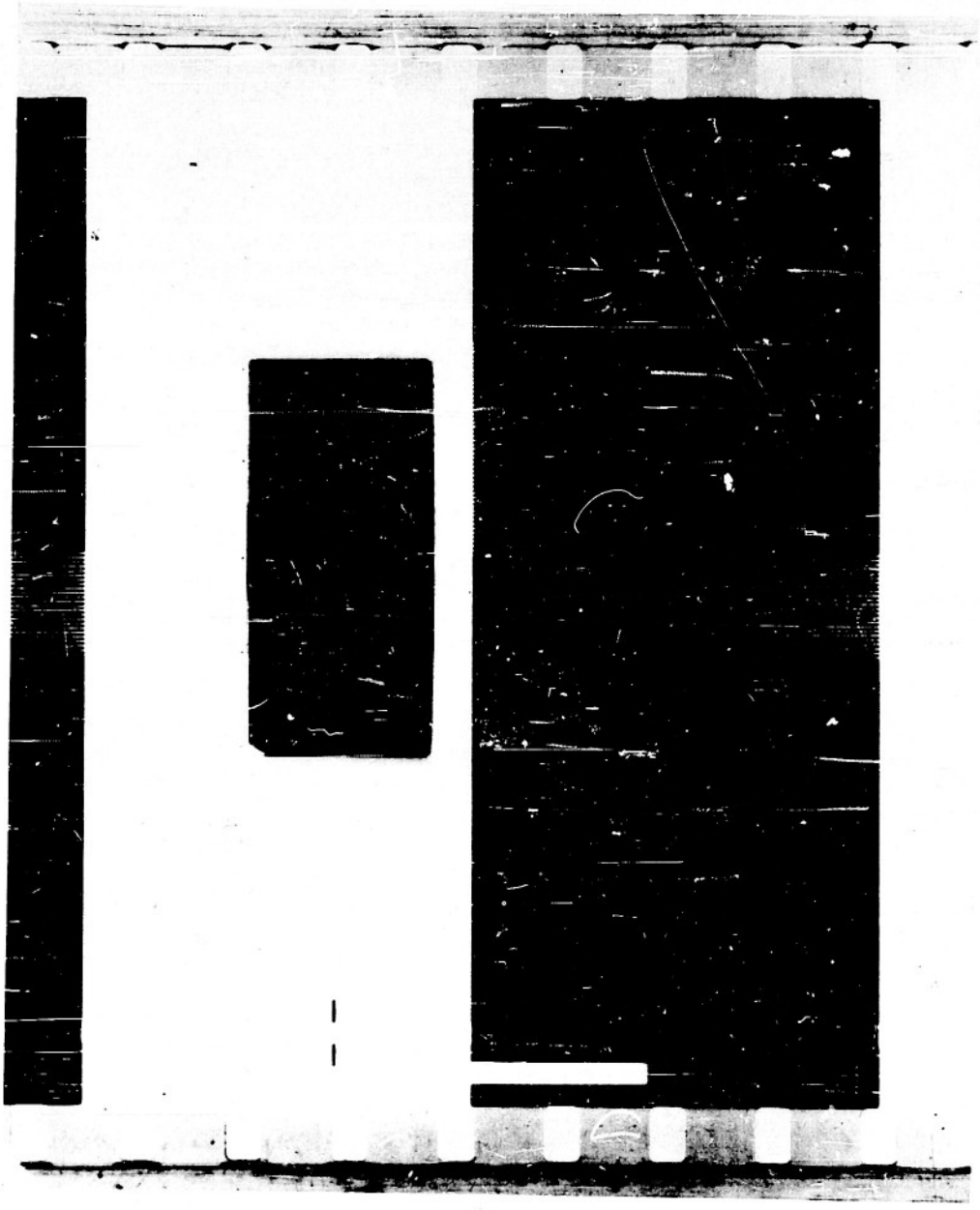


Fig. 3 - Photograph of 198 Line Film Record

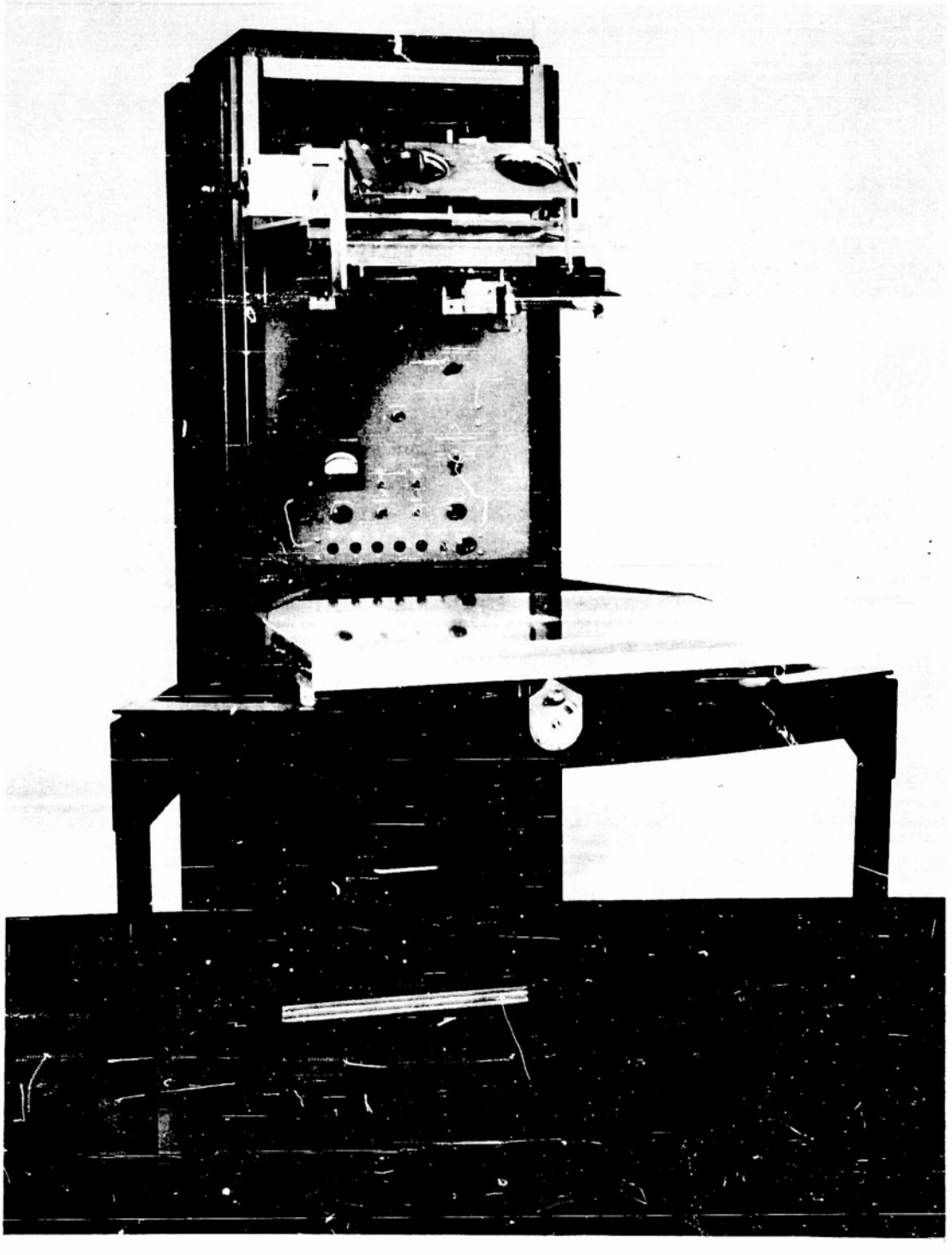
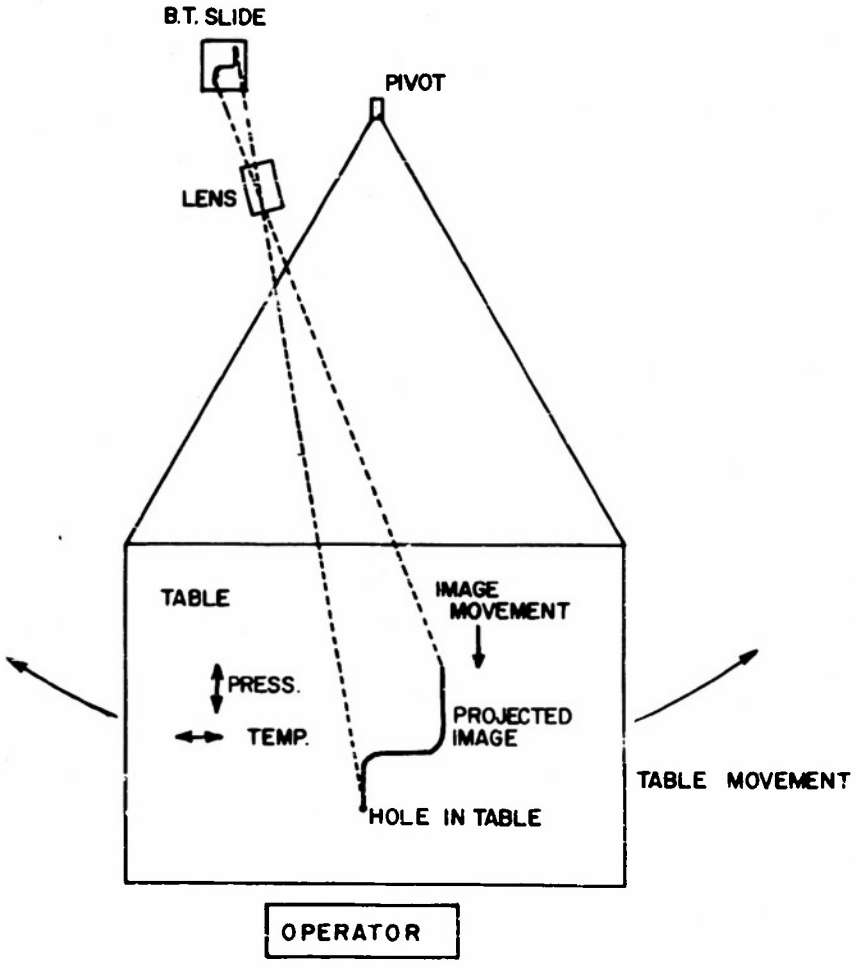


Fig. 4 - Bathermograph Slide Scanner (Cover Removed)



BATHYTHERMOGRAPH SLIDE SCANNER OPERATION

FIG 5

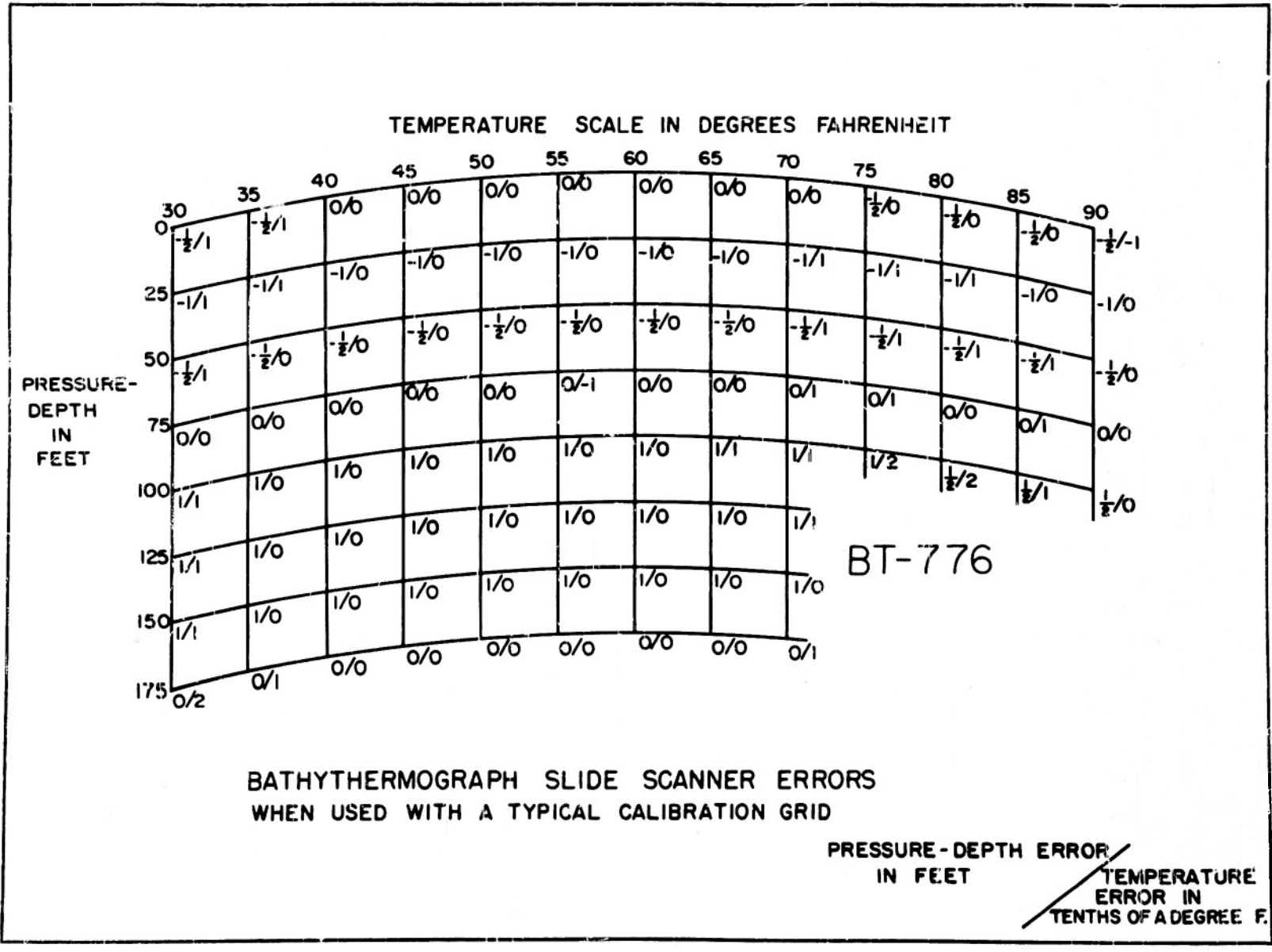


FIGURE 6

SK-6833

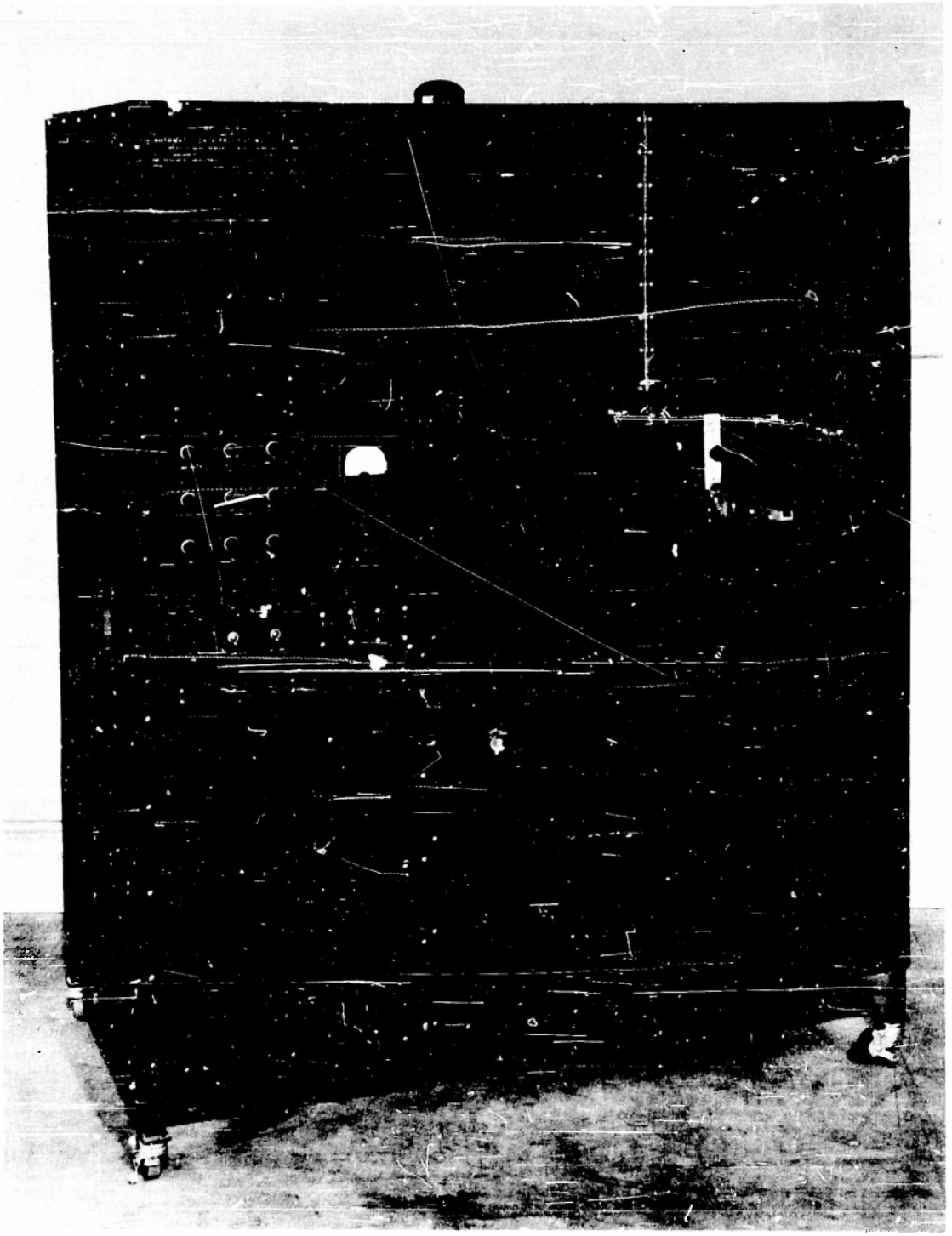


Fig. 7 - Recorder

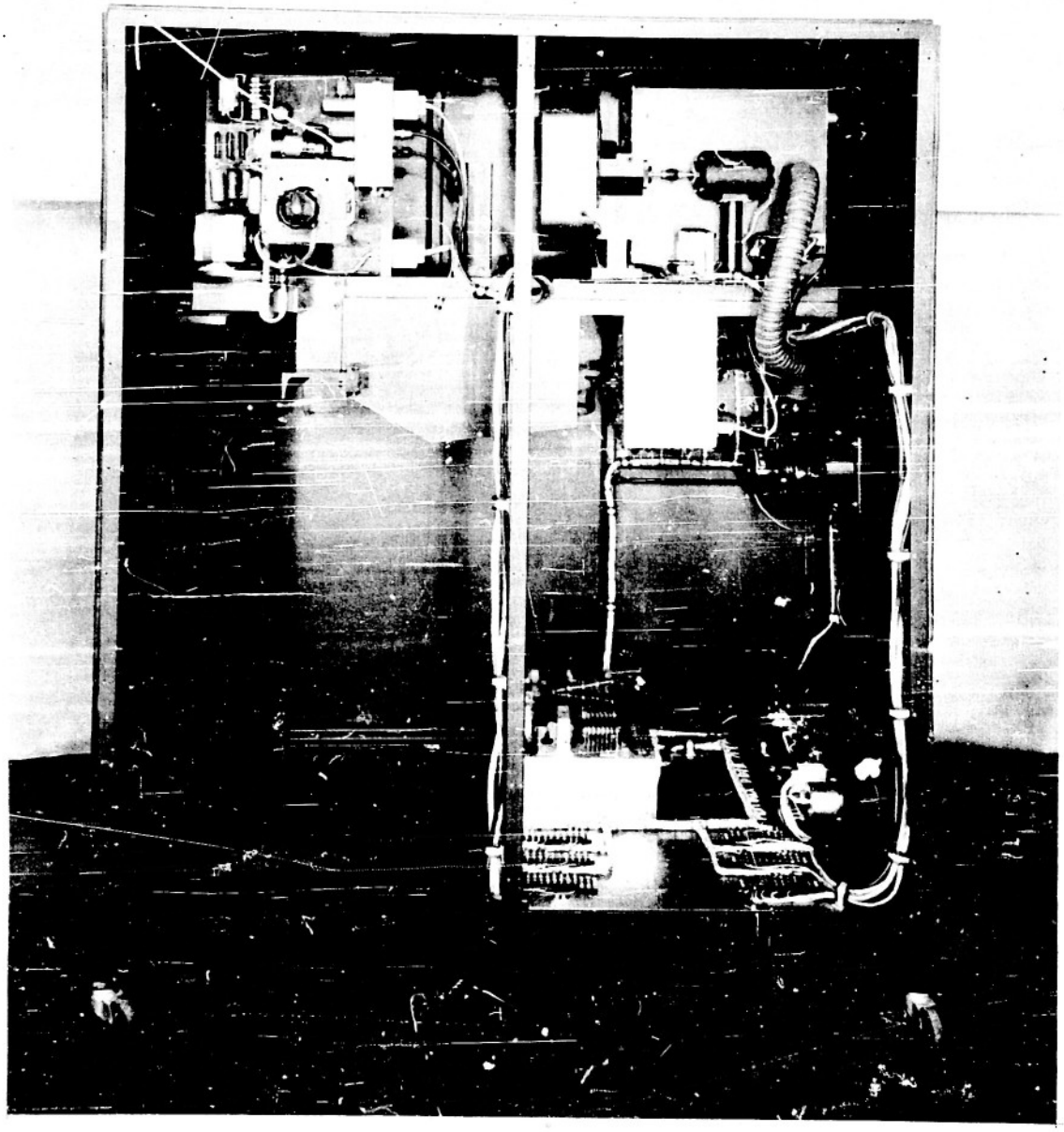


Fig. 8 - Recorder (Rear View)

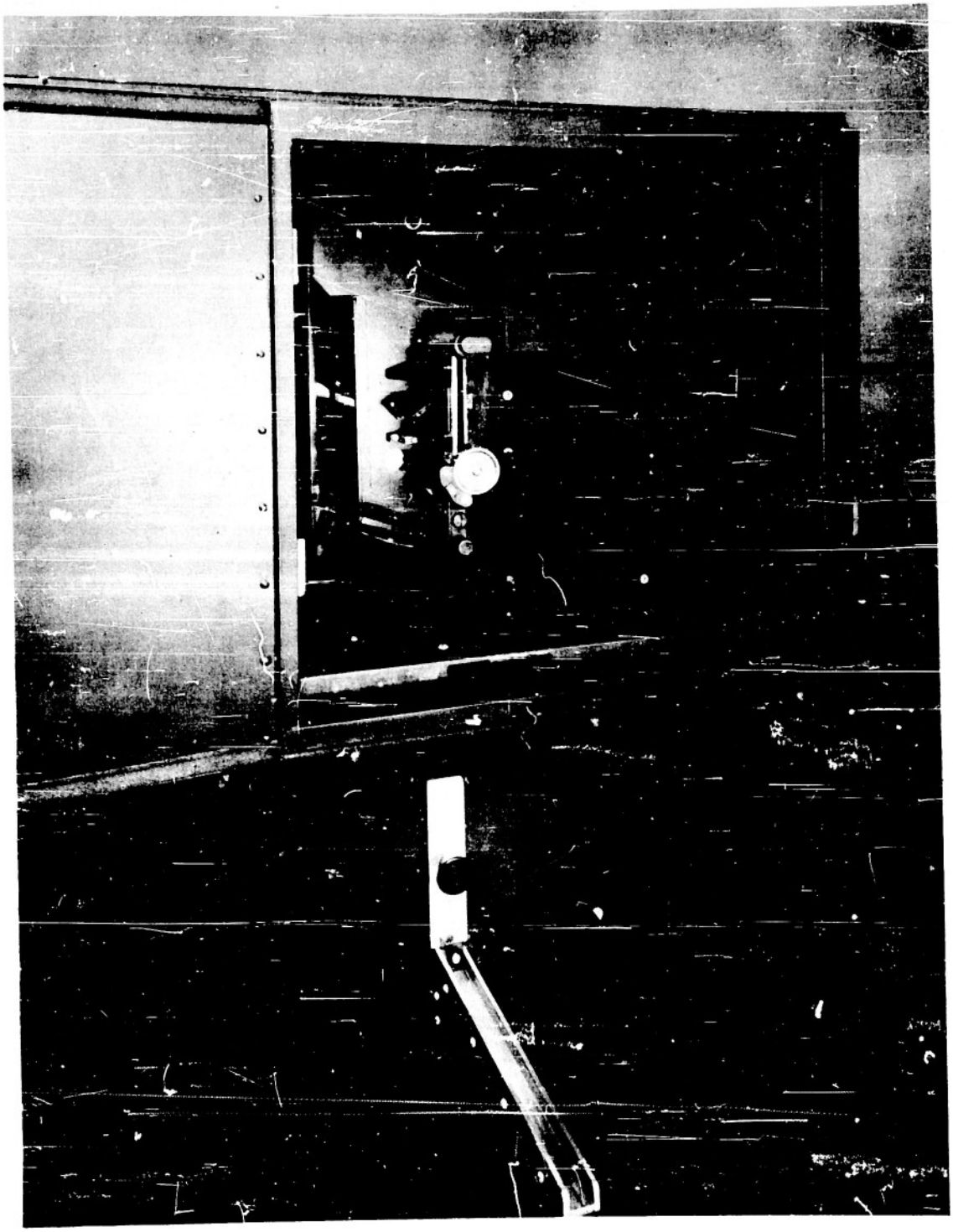


Fig. 9 - Recorder (Close-Up)

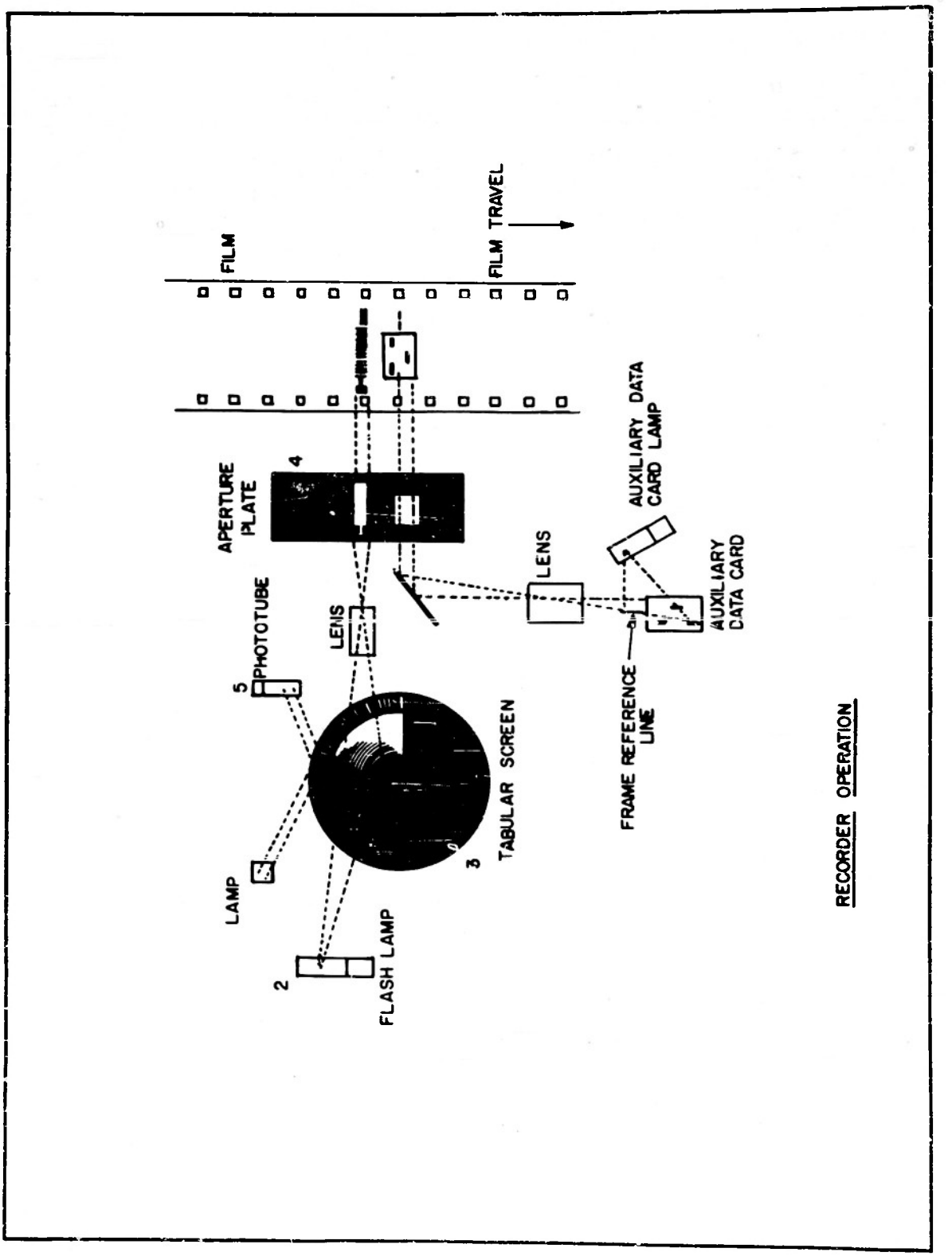

FILM
FILM TRAVEL
APERTURE PLATE
4
AUXILIARY DATA CARD LAMP
AUXILIARY DATA CARD
LENS
LENS
5
PHOTOTUBE
FRAME REFERENCE LINE
TABULAR SCREEN
3
LAMP
2
FLASH LAMP
RECORDER OPERATION

FIG 10

Fig. 11 - 599 Line Tabular Screen (1 Quadrant)

Fig. 12 - 198 Line Tabular Screen (1 Quadrant)

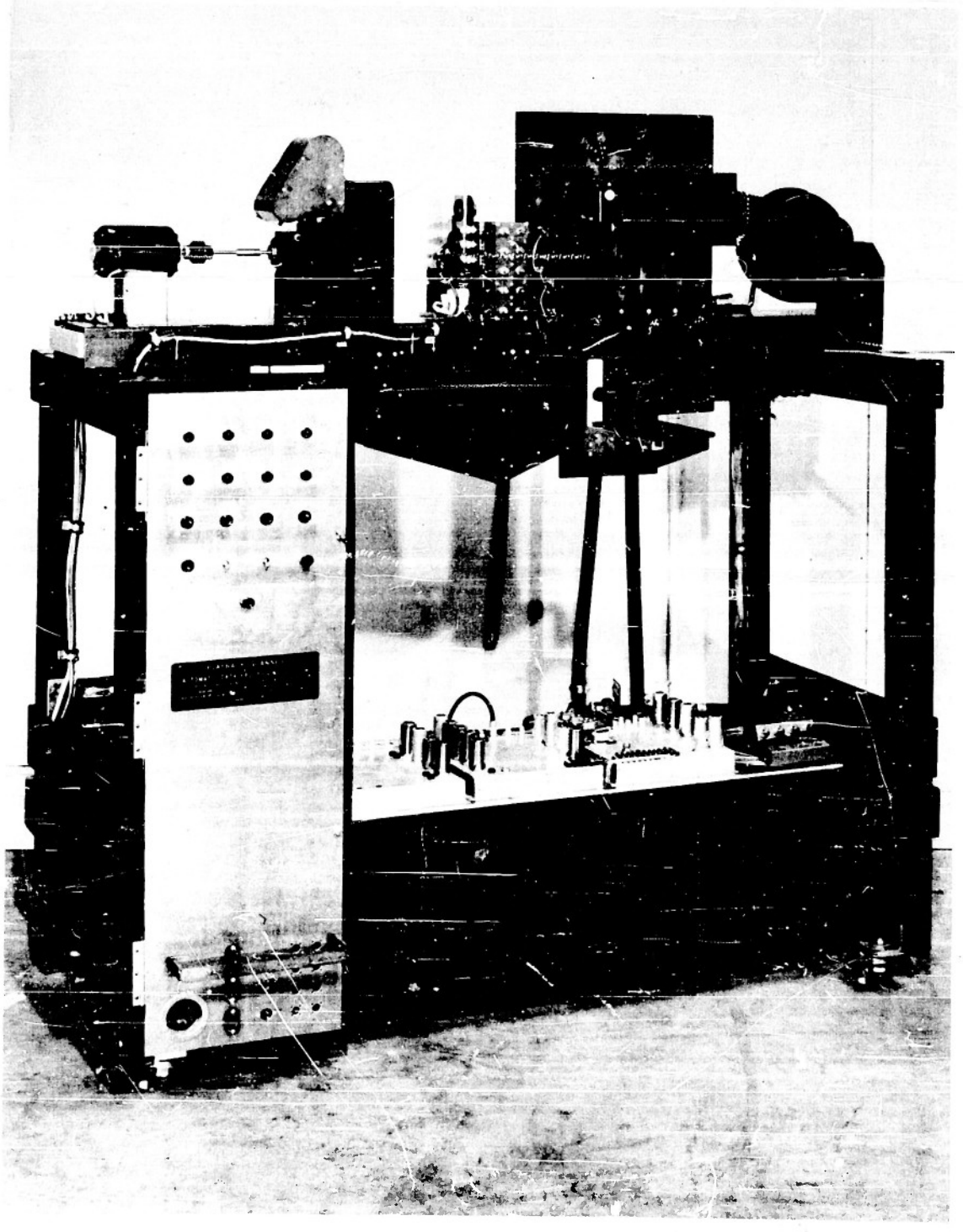


Fig. 13 - Playback Scanner

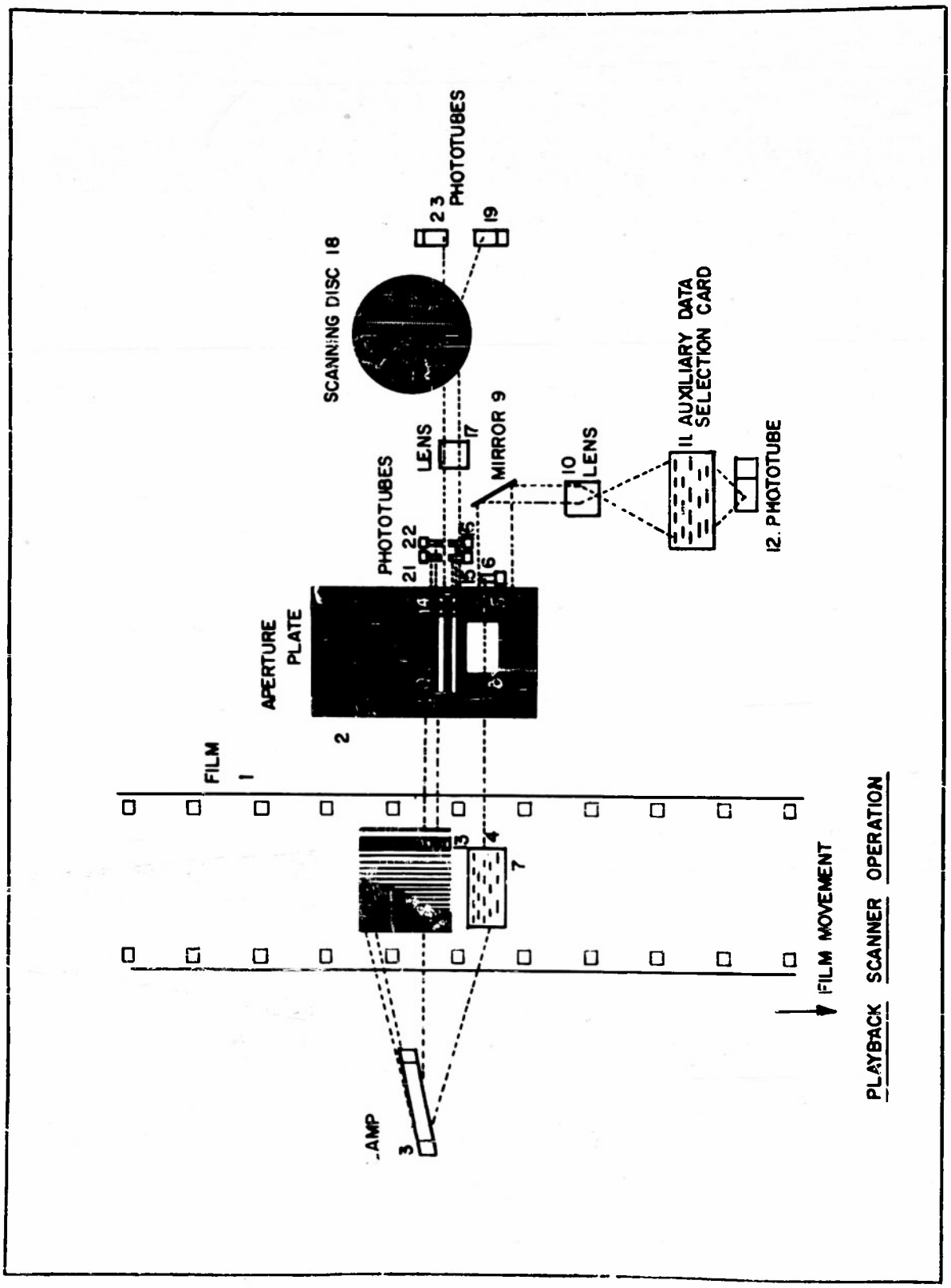

PHOTOTUBES
23
19
SCANNING DISC 18
LENS
17
MIRROR 9
10
LENS
11 AUXILIARY DATA SELECTION CARD
12. PHOTOTUBE
PHOTOTUBES
21 22
APERTURE PLATE
14
16
2
FILM
1
3
4
7
AMP
3
FILM MOVEMENT
PLAYBACK SCANNER OPERATION

FIG 14

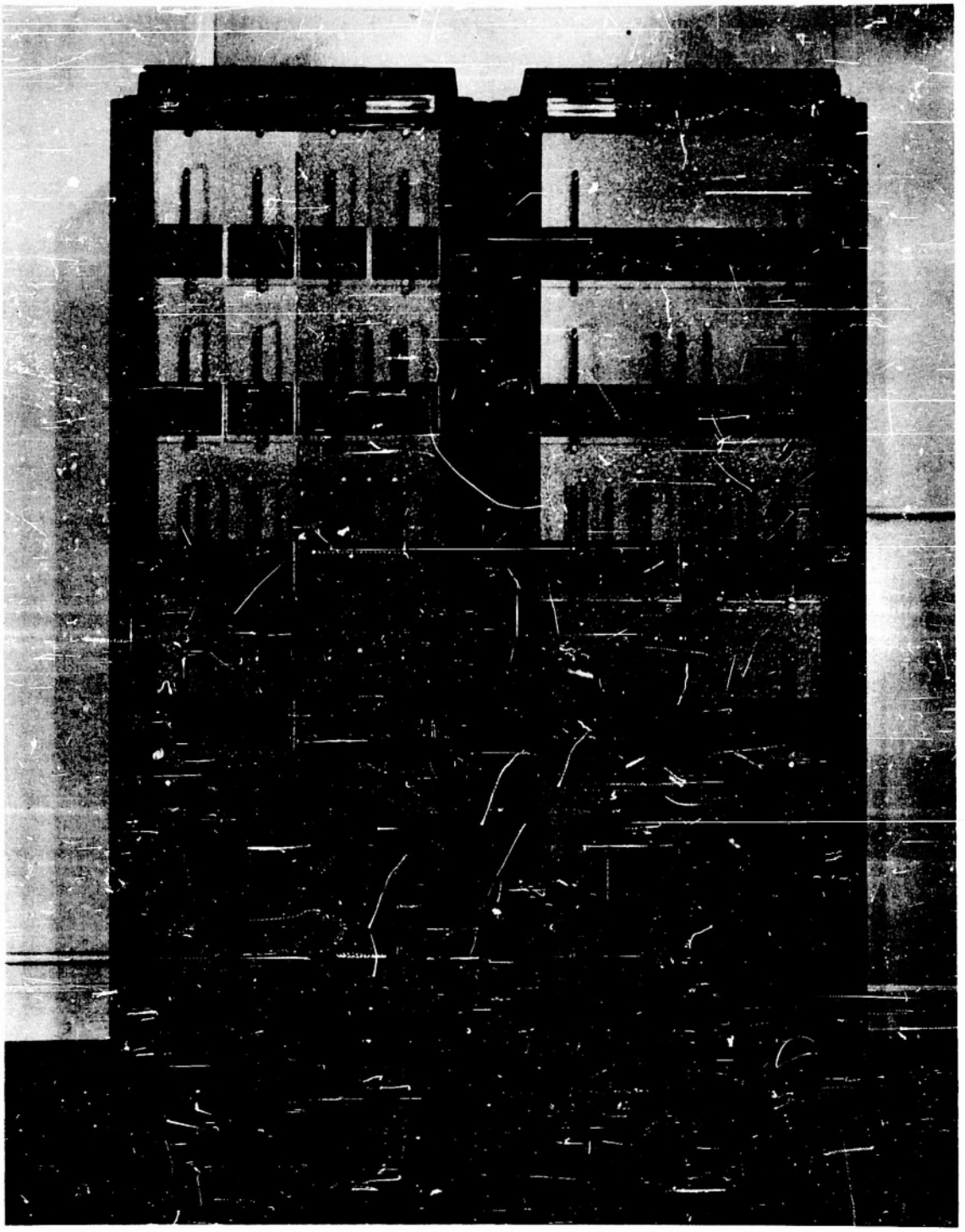


Fig. 15 - Electronics Racks

Fig. 16 - Electronics Racks (Rear View)

8027A (R02599)

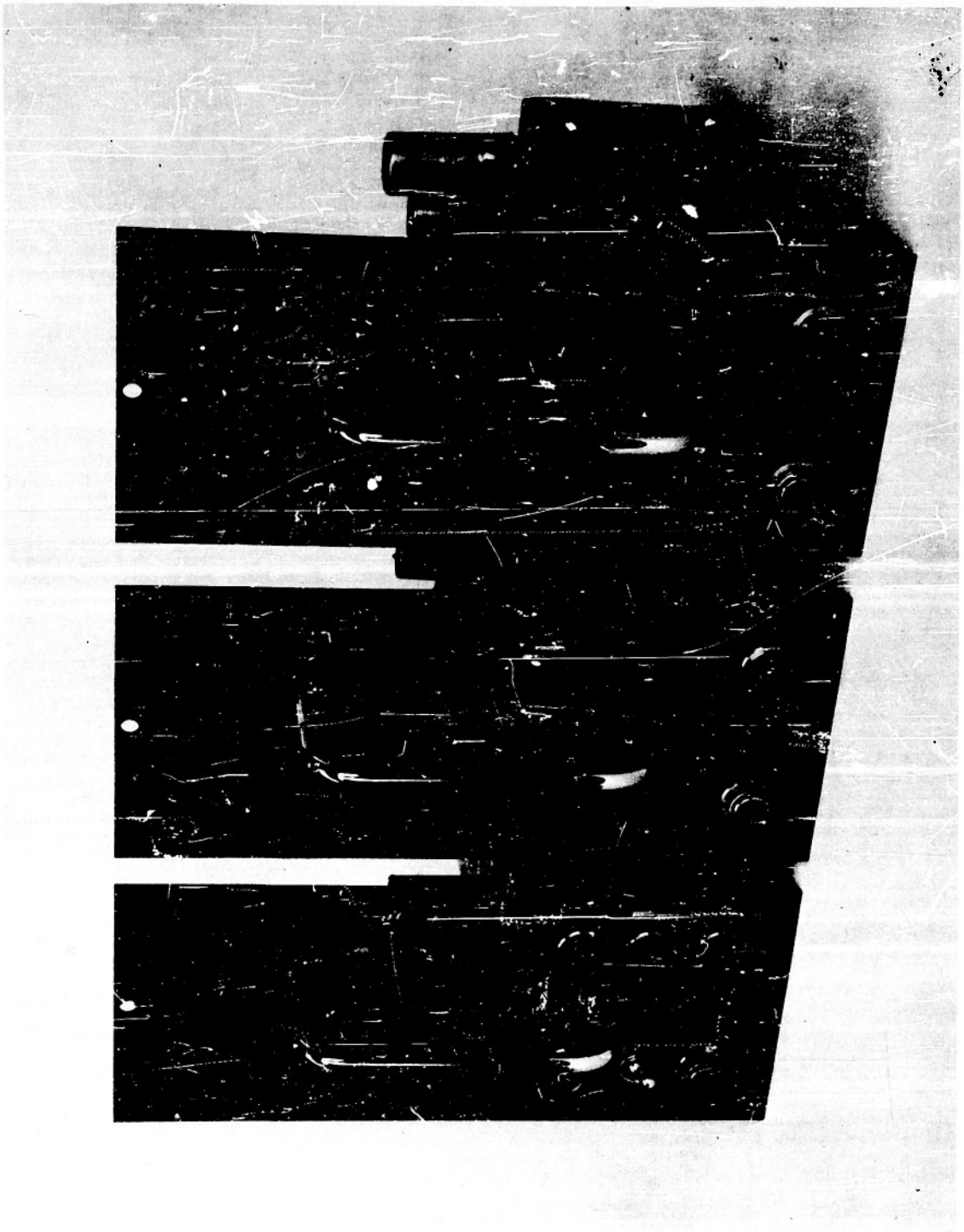


Fig. 17 - Typical Unit Chassis

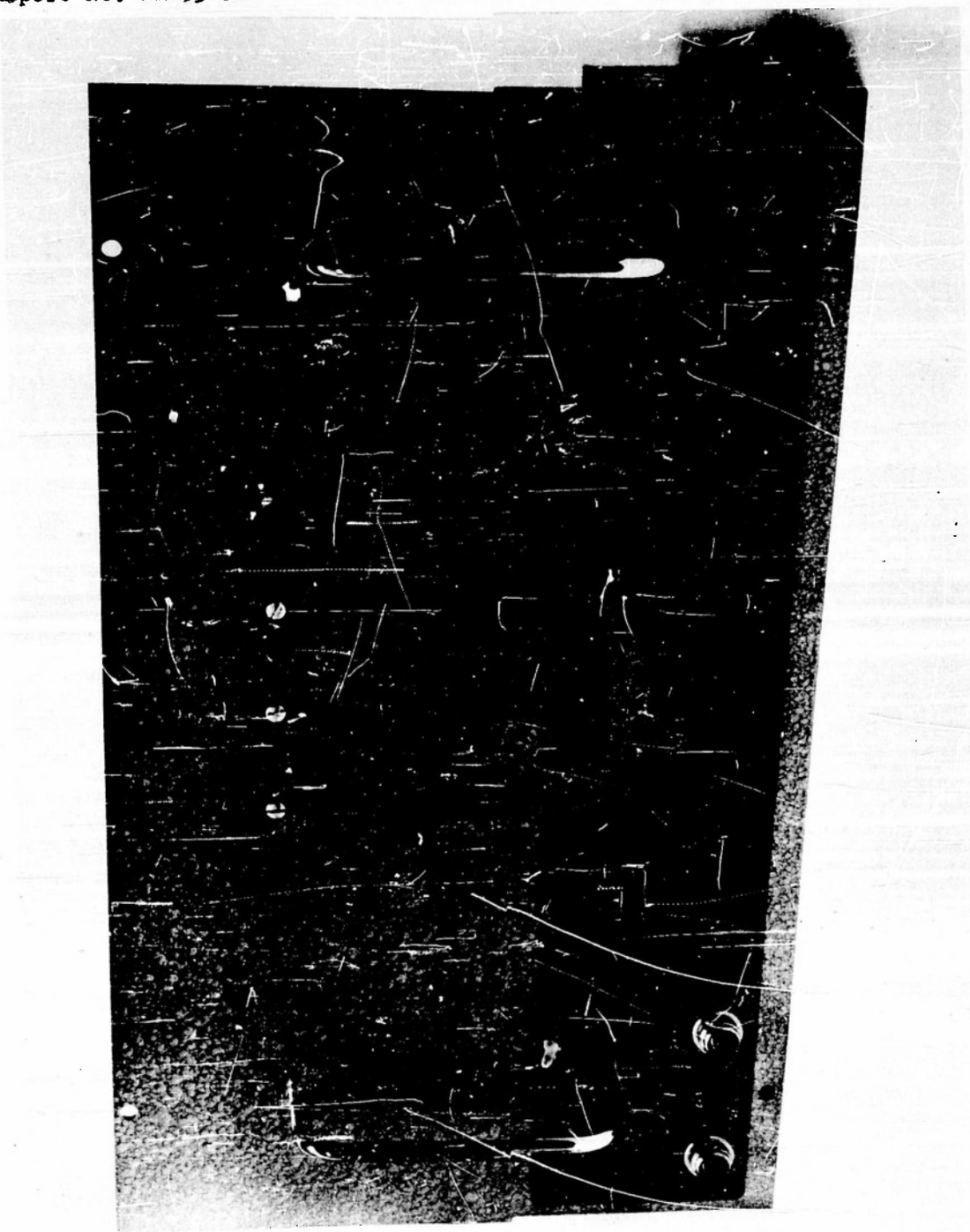
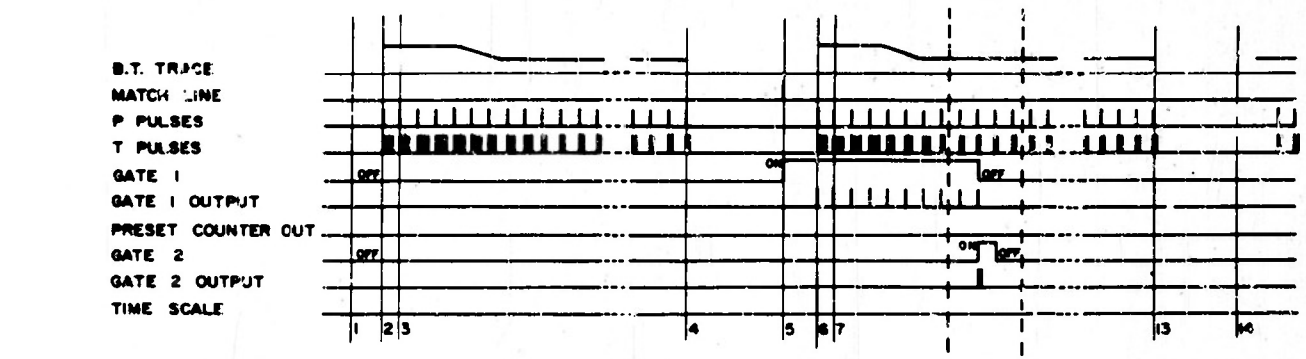
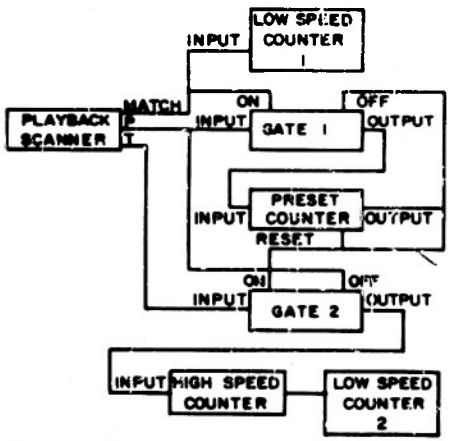
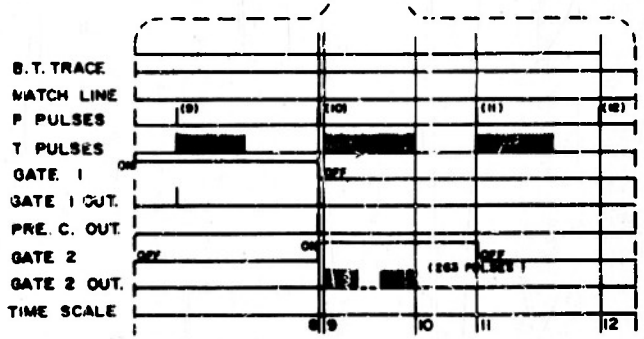


Fig. 18 - High Speed Counter







EXPANDED PORTION OF DIAGRAM

FIGURE 13

BLOCK DIAGRAM AND TIMING DIAGRAM FOR AVERAGING OPERATION USED IN EXAMPLE

SK-6947